# Study of an extrapolation chamber in a standard diagnostic radiology beam by Monte Carlo simulation

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**Abstract**: In this work, we studied the influence of the components of an extrapolation ionization chamber in its response. This study was undertaken using the MCNP-5 Monte Carlo code, and the standard diagnostic radiology quality for direct beams (RQR5). Using *tally* F6 and $2.1 \times 10^9$ simulated histories, the results showed that the chamber design and material not alter significantly the energy deposited in its sensitive volume. The collecting electrode and support board were the components with more influence on the chamber response.

**Keywords**: ionization chamber, diagnostic radiology beams, Monte Carlo Simulation.

## 1. INTRODUCTION

A few years after the discovery of X-rays by Röentgen (1895), its use was of great value in the medical field, and still is one of the most important instruments for conducting diagnostic imaging, such as computed tomography and mammography. However, with the increasing use of X-rays, adverse biological effects on patients exposed for long times to ionizing radiation were noticed. In order to perform measurements of the radiation doses, that these patients were being subjected, radiation detectors were created and, among them, the ionization chambers.

The ionization chamber is the type of detector most commonly used in the radiotherapy and diagnostic radiology fields to determine radiation doses. Ionization chambers are devices that have a sensitive volume of gas where charges, created by the interaction of direct radiation, are collected through an applied electric field, which should be large enough to collect all ions generated [Perini, 2013]. There are several types of ionization chambers, depending on the specifications of its use, and in this paper, the extrapolation ionization chamber is the chamber of interest.

Extrapolation ionization chamber, or one with variable volume, was presented by Failla in 1937 [Dias, 1996], and is based on the Bragg-Gray cavity theory. These ionization chambers have been widely studied on beta radiation beams, and were shown able to efficiently determine the dose rate on the surface of beta sources [Dias, 1996].

Currently, the Monte Carlo code has been employed to study the influence of the materials used in the construction of new radiation detectors, and the configuration of their components. This code proved to be quite accurate and efficient [Yoriyaz, 2009].

At the Institute of Energy and Nuclear Research (IPEN/CNEN-SP) an extrapolation ionization chamber was developed and characterized [Dias, 1996]. The design of this ionization chamber presents differences in relation to the commercial ones. This ionization chamber has been evaluated for dosimetry of standard beta radiation beams and low-energy X-rays, with results within the international standards [Dias and Caldas, 1998; Neves *et al*., 2012].

In this work, this extrapolation chamber was evaluated by the Monte Carlo simulation in order to determine the influence of the components on its response. This study was undertaken using the standard diagnostic radiology quality for direct beams (RQR5), in order to utilize this ionization chamber for dosimetry of diagnostic radiology beams.

## 2. MATERIALS AND METHODS

The technical specifications of the ionization chamber evaluated in this work are presented in table 1.

**Table 1.** Ionization chamber technical specifications.

| Characteristics | Specifications |
|---|---|
| Electrode material | Graphite |
| Electrode thickness | 3 mm |
| Electrode diameter | 30 mm |
| Entrance window material | Aluminized polyethylene terephthalate (0.84 mg/cm²) |
| Wall material | PMMA |
| Sensitive volume material | Atmospheric air |
| Insulator material | PMMA |

In order to study this ionization chamber the MCNP-5 Monte Carlo code was utilized. This code was developed and it is maintained by the Los Alamos National Laboratory [Pelowitz, 2011]. It consists of a multipurpose code that can be used for transport (or coupled transport) of neutrons, photons and electrons.

This software was used to determine the influence of the components of the extrapolation ionization chamber on its response, utilizing a standard radiodiagnostic beam (RQR5). The radiodiagnostic spectrum was provided by the Primary Standard Laboratory of Germany, *Physikalisch Technische Bundesanstalt* (PTB) [Büermann, 2012]. This spectrum was acquired at the PTB in a YXLON X-ray equipment, with a distance of 100.0 cm from the focal point of the X-ray tube, the same distance used in the simulations.

In the simulations, the spectrum used was the standard radiation quality RQR5. The main characteristics of this standard quality are: tube voltage of 70 kV, half-value layer of 2.58 mmAl and air kerma rate of (37.88 ± 0.32) mGy/min.

The number of simulated histories was $2.1 \times 10^9$, and the deposited energy was obtained using *tally* F6.

## 3. RESULTS AND DISCUSSION

The main components of the extrapolation ionization chamber were studied in order to evaluate their influences on the deposited energy in the sensitive volume of the ionization chamber.

The extrapolation chamber simulated with its components is showed in figure 1. The influence of each studied component was obtained as the ratio of the dose to the gas in the ionization chamber (atmospheric air) without the studied component to that with the whole chamber. The obtained ratios are listed in table 2.

The results presented in table 2 show that the collecting electrode and support board have more influence on the chamber response. These components are closer to the sensitive volume, and their influences are greater than other components. Although, the insulators are close to sensitive volume, they have a very small size and had no influence on the chamber response.

In the work of Muir and Rogers [Muir and Rogers, 2011] the influence of the collecting electrode, made of aluminum, was up to 50.0% for an 200 kVp incident beam, and, therefore, the influence of the collecting electrode, made of graphite, in this work, is smaller than the literature results.

The results indicate that the chamber design and material does not alter significantly the energy deposited in the sensitive volume of the ionization chamber.

The uncertainties, presented in Table 2, for all Monte Carlo simulations are the Type A, with a coverage factor of 2.

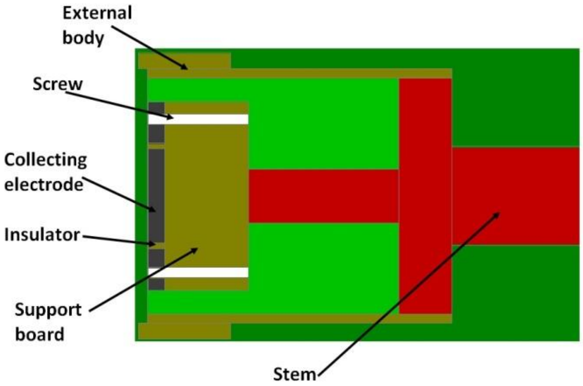


**Figure 1.** Extrapolation ionization chamber simulated by the MCNP Monte Carlo code.

**Table 2.** Influence of the ionization chamber components on the energy deposition in the sensitive volume for the RQR5 radiation quality.

| Studied component | Ratios of the energy deposition |
|---|---|
| Stem | 1.00±0.01 |
| Collecting electrode | 0.96±0.01 |
| External body | 0.99±0.01 |
| Insulators | 1.00±0.01 |
| Support board | 0.91±0.01 |
| Screws | 1.00±0.01 |

## 4. CONCLUSIONS

In this work, an extrapolation ionization chamber, with all dimensions, materials and geometrical arrangement known, was simulated by Monte

Carlo code. This code was employed to study this ion chamber configuration for the RQR5 standard diagnostic radiology beam. The results point out a small influence of the studied components on the chamber response, and it presented several advantages: low-cost, easy assembling and robustness.

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